Parasitism

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In biology/ecology, **parasitism** is a non-mutual symbiotic relationship between species, where one species, the **parasite**, benefits at the expense of the other, the host. Traditionally *parasite* (in biological usage) referred primarily to organisms visible to the naked eye, or macroparasites (such as helminths). Parasites can be microparasites, which are typically smaller, such as protozoa,[1][2] viruses, and bacteria.[3] Examples of parasites include the plants mistletoe and cuscuta, and animals such as hookworms.

Brood parasitism is a form of parasitism.

Unlike predators, parasites typically do not kill their host, are generally much smaller than their host, and will often live in or on their host for an extended period. Both are special cases of consumer-resource interactions.[4] Parasites show a high degree of specialization, and reproduce at a faster rate than their hosts. Classic examples of parasitism include interactions between vertebrate hosts and tapeworms, flukes, the *Plasmodium* species, and fleas. Parasitism differs from the parasitoid relationship in that parasitoids generally kill their hosts.[5][6][7]

A *Tetragnatha montana* spider parasitised by an *Acrodactyla quadrisculpta* larva

Parasites reduce host biological fitness by general or specialized pathology, such as parasitic castration and impairment of secondary sex characteristics, to the modification of host behavior. Parasites increase their own fitness by exploiting hosts for resources necessary for their survival, e.g. food, water, heat, habitat, and transmission. Although parasitism applies unambiguously to many cases, it is part of a continuum of types of interactions between species, rather than an exclusive category. In many cases, it is difficult to demonstrate harm to the host. In others, there may be no apparent specialization on the part of the parasite, or the interaction between the organisms may remain short-lived.

A *Lithognathus* fish parasitised by a *Cymothoa exigua* parasite

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Etymology

First used in English 1539, the word *parasite* comes from the Medieval French *parasite*, from the Latin *parasitus*, the latinisation of the Greek *παράσιτος* (*parasitos*), "one who eats at the table of another"[8] and that from *παρά* (*para*), "beside, by"[9] + *σῖτος* (*sitos*), "wheat".[10] Coined in English in 1611, the word *parasitism* comes from the Greek *παρά* (*para*) + *σιτισμός* (*sitismos*) "feeding, fattening".[11] In its original sense, it was not strictly pejorative in nature;[12] being a *parasitos* was an accepted lifestyle, whereby a person could live off the hospitality of others, and in return provide "flattery, simple services, and a willingness to endure humiliation".[13]

Types

Parasites are classified based on their interactions with their hosts and on their life cycles. An **obligate parasite** is totally dependent on the host to complete its life cycle, while a **facultative parasite** is not. A direct parasite has only one host while an indirect parasite has multiple hosts. For indirect parasites, there will always be a definitive host and an intermediate host.[14][15]

Human head lice (*Pediculus humanus capitis*) are ectoparasites.

Parasites that live on the outside of the host, either on the skin or the outgrowths of the skin, are called **ectoparasites** (e.g. lice, fleas, and some mites).[16]

Those that live inside the host are called **endoparasites** (including all parasitic worms). Endoparasites can exist in one of two forms: **intercellular parasites** (inhabiting spaces in the host's body) or **intracellular parasites** (inhabiting cells in the host's body). Intracellular parasites, such as protozoa, bacteria or viruses, tend to rely on a third organism, which is generally known as the carrier or vector.[17] The vector does the job of transmitting them to the host. An example of this interaction is the transmission of malaria, caused by a protozoan of the genus *Plasmodium*, to humans by the bite of an anopheline mosquito.

Those parasites living in an intermediate position, being half-ectoparasites and half-endoparasites, are called **mesoparasites.**

An **epiparasite** is one that feeds on another parasite. This relationship is also sometimes referred to as *hyperparasitism*, exemplified by a protozoan (the hyperparasite) living in the digestive tract of a flea living on a dog.

Schistosoma mansoni is an endoparasite that lives in human blood vessels.

Social parasites take advantage of interactions between members of social organisms such as ants, termites, and bumblebees. Examples include *Phengaris arion*, a butterfly whose larvae employ mimicry to parasitize certain species of ants,[18] *Bombus bohemicus*, a bumblebee who invades the hives of other species of bee and takes over reproduction, their young raised by host workers, and *Melipona scutellaris*, a eusocial bee where virgin queens escape killer workers and invade another colony without a queen.[19] An extreme example of social parasitism is the ant species of *Tetramorium inquilinum* of the Alps, which spend their whole lives on the back of *Tetramorium* host ants. With tiny and deprecated bodies they have evolved for one single task: holding on to their host. If they fall off, they most likely would not have the strength to climb back on top of another ant, and eventually they will die.[20]

In **kleptoparasitism** (from the Greek κλέπτης (kleptes), thief), parasites appropriate food gathered by the host. An example is the **brood parasitism** practiced by cowbirds, whydahs, cuckoos, and black-headed ducks which do not build nests of their own and leave their eggs in nests of other species. The host behaves as a "babysitter" as they raise the young as their own. If the host removes the cuckoo's eggs, some cuckoos will return and attack the nest to compel host birds to remain subject to this parasitism.[21]

Intraspecific social parasitism may also occur. One example of this is *parasitic nursing*, where some individuals take milk from unrelated females. In wedge-capped capuchins, higher ranking females sometimes take milk from low ranking females without any reciprocation. The high ranking females benefit at the expense of the low ranking females.[22]

Parasitism can take the form of isolated *cheating* or *exploitation* among more generalized mutualistic interactions. For example, broad classes of plants and fungi exchange carbon and nutrients in common mutualistic mycorrhizal relationships; however, some plant species known as myco-heterotrophs "cheat" by taking carbon from a fungus rather than donating it.

An **adelpho-parasite** (from the Greek αδελφός (adelphos), brother) is a parasite in which the host species is closely related to the parasite, often being a member of the same family or genus. An example of this is the citrus blackfly parasitoid, *Encarsia perplexa*, unmated females of which may lay haploid eggs in the fully developed larvae of their own species. These result in the production of male offspring.[23] The marine worm *Bonellia viridis* has a similar reproductive strategy, although the larvae are planktonic.[24]

Autoinfection is the infection of a primary host with a parasite, particularly a helminth, in such a way that the complete life cycle of the parasite happens in a single organism, without the involvement of another host. Therefore, the primary host is at the same time the secondary host of the parasite. Some of the organisms where autoinfection occurs are *Strongyloides stercoralis*, *Enterobius vermicularis*, *Taenia solium*, and

Hymenolepis nana. Strongyloidiasis for example involves premature transformation of noninfective larvae in infective larvae, which can then penetrate the intestinal mucosa (internal autoinfection) or the skin of the perineal area (external autoinfection). Infection can be maintained by repeated migratory cycles for the remainder of the person's life.

Host defenses

Animal defenses

Skin

The first line of defense against invading parasites is the skin. Skin is made up of layers of dead cells and acts as a physical barrier to invading organisms. These dead cells contain the protein keratin, which makes skin tough and waterproof. Most microorganisms needs a moist environment to survive. By keeping the skin dry, it prevents invading organisms from colonizing. Furthermore, human skin also secretes sebum, which is toxic to most microorganisms.[25]

Mouth

The mouth contains saliva, which prevents foreign organisms from getting into the body orally. Furthermore, the mouth also contains lysozyme, an enzyme found in tears and the saliva. This enzyme breaks down cell walls of invading microorganisms.[25]

Stomach

Should the organism pass the mouth, the stomach is the next line of defense. The stomach contains hydrochloric acid and gastric acids, which makes its pH level around 2. In this environment, the acidity of the stomach helps kill most microorganisms that try to invade the body through the gastric intestinal tract.[25]

Eyes

Parasites can also invade the body through the eyes. The lashes on the eyelid prevents invading microorganisms from entering the eye in the first place. Even if the microorganism does get into the eye, tears contain the enzyme lysozyme, which will kill most invading microorganisms.[25]

Immune system

Should the parasite enter the body, the immune system is a vertebrate’s major defense against parasitic invasion. The immune system is made up of different families of molecules. These include serum proteins and pattern recognition receptors (PRRs). PRRs are intracellular and cellular receptors that activate dendritic cells, which in turn activate the adaptive immune system’s lymphocytes. Lymphocytes such as the T cells and antibody producing B cells with variable receptors that recognize parasites.[26]

Insect defenses

Insects often adapt their nests to aid in parasite defense. For example, one of the key reasons the *Polistes* *canadensis* nests across multiple combs rather than building a single comb like much of the rest of its genus is as a defense mechanism against the infestation of tineid moths. The tineid moth lays its eggs within the wasps' nests and then these eggs hatch into larvae that can burrow from cell to cell and prey on wasp pupae. Adult wasps attempt to remove and kill moth eggs and larvae by chewing down the edges of cells, coating the cells with an oral secretion that gives the nest a dark brownish appearance.[27]

Plant defenses

In response to parasitic attack, plants undergo a series of metabolic and biochemical reaction pathways that will enact defensive responses. For example, parasitic invasion causes an increase in the jasmonic acid-insensitivel (JA) and NahG (SA) pathway.[28] These pathways produce chemicals that induce defensive responses, such as the production of chemicals or defensive molecules to fight off the attack. Different biochemical pathways are activated by different parasites.[29] In general, there are two types of responses that can be activated by the pathways. Plants can either initiate a specific or non-specific response.[30] Specific responses involve gene-gene recognition of the plant and parasite. This can be mediated by the ability of the plant's cell receptors recognizing and binding molecules that are located on the cell surface of parasites. Once the plant's receptors recognizes the parasite, the plant localizes the defensive compounds to that area creating a hypersensitive response. This form of defense mechanism localizes the area of attack and keeps the parasite from spreading. Furthermore, a specific response against parasitic attack prevents the plants from wasting its energy by increasing defenses where it's not need. However, specific defensive responses only target specific parasites. If the plant lacks the ability to recognize a parasite, specific defense responses won't be activated. Nonspecific defensive responses work against all parasites. These responses are active over time and are systematic, meaning that the responses are not confined to an area of the plant, but rather spread throughout the entirety of the organism. However, nonspecific responses are energy costly, since the plant has to ensure that the genes producing the nonspecific responses are always expressed.[30]

Evolutionary aspects

Parasitism has arisen independently many times. Depending on the definition used, as many as half of all animals have at least one parasitic phase in their life cycles,[31] and is frequent in plants and fungi. Almost all free-living animals are host to one or more parasitic taxa.[31]

Parasites evolve in response to their hosts' defences, sometimes in a manner specific to a particular host taxon and specializing to the point where they infect only a single species. Such narrow host specificity can be costly over evolutionary time, however, if the host species becomes extinct. Therefore, many parasites can infect a variety of more or less closely related host species, with different success rates.

In turn, host defenses coevolve in response to attacks by parasites. Theoretically, parasites may have an advantage in this evolutionary arms race because their generation time commonly is shorter. Hosts reproduce less quickly than parasites, and therefore have fewer chances to adapt than their parasites do over a given span of time.

Long-term coevolution sometimes leads to a relatively stable relationship tending to commensalism or mutualism, as, all else being equal, it is in the evolutionary interest of the parasite that its host thrives. A parasite may evolve to become less harmful for its host or a host may evolve to cope with the unavoidable presence of a parasite—to the point that the parasite's absence causes the host harm. For example, although animals infected with parasitic worms are often clearly harmed, and therefore parasitized, such infections may also reduce the prevalence and effects of autoimmune disorders in animal hosts, including humans.[33] In a more extreme example, some nematode worms cannot reproduce, or even survive, without infection by Wolbachia bacteria.[34]

Restoration of a *Tyrannosaurus* with parasite infections. A 2009 study showed that holes in the skulls of several specimens might have been caused by *Trichomonas*-like parasites[32]

Competition between parasites tends to favor faster reproducing and therefore more virulent parasites. Parasites whose life cycle involves the death of the host, to exit the present host and sometimes to enter the next, evolve to be more virulent or even alter the behavior or other properties of the host to make it more vulnerable to predators. Parasites that reproduce largely to the offspring of the previous host tend to become less virulent or mutualist, so that its hosts reproduce more effectively.[3]

The presumption of a shared evolutionary history between parasites and hosts can sometimes elucidate how host taxa are related. For instance, there has been dispute about whether flamingos are more closely related to the storks and their relatives, or to ducks, geese and their relatives. The fact that flamingos share parasites with ducks and geese is evidence these groups may be more closely related to each other than either is to storks.

Parasitism is part of one explanation for the evolution of secondary sex characteristics seen in breeding males throughout the animal world, such as the plumage of male peacocks and manes of male lions. According to this theory, female hosts select males for breeding based on such characteristics because they indicate resistance to parasites and other disease.

Co-speciation

In rare cases, a parasite may even undergo co-speciation with its host. One particularly remarkable example of co-speciation exists between the simian foamy virus (SFV) and its primate hosts. In one study, the phylogenies of SFV polymerase and the mitochondrial cytochrome oxidase subunit II from African and Asian primates were compared.[35] Surprisingly, the phylogenetic trees were very congruent in branching order and divergence times. Thus, the simian foamy viruses may have co-speciated with Old World primates for at least 30 million years.

Evolutionary events like host switch, host shift, the duplication or extinction of parasite species (without similar events on the host phylogeny) often erode topographical similarities between host and parasite phylogenies.

Ecology

Quantitative ecology

A single parasite species usually has an aggregated distribution across host individuals, which means that most hosts harbor few parasites, while a few hosts carry the vast majority of parasite individuals. This poses considerable problems for students of parasite ecology: the use of parametric statistics should be avoided. Log-transformation of data before the application of parametric test, or the use of non-parametric statistics is recommended by several authors. However, this can give rise to further problems.[36] Therefore, modern day quantitative parasitology is based on more advanced biostatistical methods.

Diversity ecology

Hosts represent discrete habitat patches that can be occupied by parasites. A hierarchical set of terminology has come into use to describe parasite assemblages at different host scales.

Infrapopulation
: All the parasites of one species in a single individual host.

Metapopulation
: All the parasites of one species in a host population.

Infracommunity
: All the parasites of all species in a single individual host.

Component community
: All the parasites of all species in a host population.

Compound community
: All the parasites of all species in all host species in an ecosystem.

The diversity ecology of parasites differs markedly from that of free-living organisms. For free-living organisms, diversity ecology features many strong conceptual frameworks including Robert MacArthur and E. O. Wilson's theory of island biogeography, Jared Diamond's assembly rules and, more recently, null models such as Stephen Hubbell's unified neutral theory of biodiversity and biogeography. Frameworks are not so well-developed for parasites and in many ways they do not fit the free-living models. For example, island biogeography is predicated on fixed spatial relationships between habitat patches ("sinks"), usually with reference to a mainland ("source"). Parasites inhabit hosts, which represent mobile habitat patches with dynamic spatial relationships. There is no true "mainland" other than the sum of hosts (host population), so parasite component communities in host populations are metacommunities.

Nonetheless, different types of parasite assemblages have been recognized in host individuals and populations, and many of the patterns observed for free-living organisms are also pervasive among parasite assemblages. The most prominent of these is the interactive-isolationist continuum. This proposes that parasite assemblages occur along a cline from interactive communities, where niches are saturated and interspecific competition is high, to isolationist communities, where there are many vacant niches and interspecific interaction is not as important as stochastic factors in providing structure to the community. Whether this is so, or whether community patterns simply reflect the sum of underlying species distributions (no real "structure" to the community), has not yet been established.

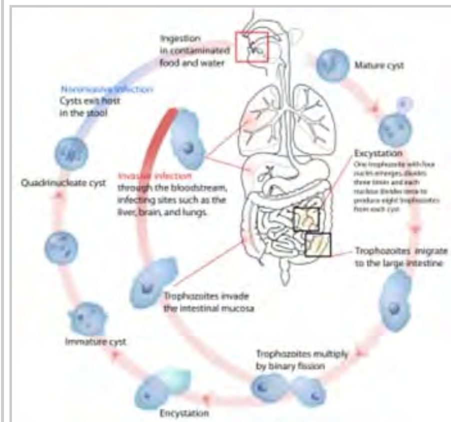
Adaptation

Parasites infect hosts that exist within their same geographical area (sympatric) more effectively. This phenomenon supports the "Red Queen hypothesis—which states that interactions between species (such as host and parasites) lead to constant natural selection for adaptation and counter adaptation."[37] The parasites track the locally common host phenotypes, therefore the parasites are less infective to allopatric (from different geographical region) hosts.

Experiments published in 2000 discuss the analysis of two different snail populations from two different sources—Lake Ianthe and Lake Poerua in New Zealand. The populations were exposed to two pure parasites (digenetic trematode) taken from the same lakes. In the experiment, the snails were infected by their sympatric parasites, allopatric parasites and mixed sources of parasites. The results suggest that the parasites were more highly effective in infecting their sympatric snails than their allopatric snails. Though the allopatric snails were still infected by the parasites, the infectivity was much less when compared to the sympatric snails. Hence, the parasites were found to have adapted to infecting local populations of snails.[37]

Transmission

Parasites have a variety of methods to infect hosts. For example, the *Acanthamoeba* enters the body when the environment is not hostile, and *Strongyloides stercoralis* enters the body when a host steps on infected ground while barefoot. Many parasites enter the food of their hosts and wait to be eaten. *Plasmodium malariae* uses a mosquito host to transmit malaria, and *Loa loa* parasites use deer flies to enter hosts.



Life cycle of *Entamoeba histolytica*, an anaerobic parasitic protozoan.

Parasites inhabit living organisms and therefore face problems that free-living organisms do not. Hosts, the only habitats in which parasites can survive, actively try to avoid, repel, and destroy parasites. Parasites employ numerous strategies for getting from one host to another, a process sometimes referred to as parasite *transmission* or *colonization*.

Some endoparasites infect their host by penetrating its external surface, while others must be ingested. Once inside the host, adult endoparasites need to shed offspring into the external environment to infect other hosts. Many adult endoparasites reside in the host's gastrointestinal tract, where offspring can be shed along with host excreta. Adult stages of tapeworms, thorny-headed worms and most flukes use this method.

Among protozoan endoparasites, such as the malarial parasites and trypanosomes, infective stages in the host's blood are transported to new hosts by biting-insects, or vectors.

Larval stages of endoparasites often infect sites in the host other than the blood or gastrointestinal tract. In many such cases, larval endoparasites require their host to be consumed by the next host in the parasite's life cycle in order to survive and reproduce. Alternatively, larval endoparasites may shed free-living transmission stages that migrate through the host's tissue into the external environment, where they actively search for or await ingestion by other hosts. The foregoing strategies are used, variously, by larval stages of tapeworms, thorny-headed worms, flukes and parasitic roundworms.

Some ectoparasites, such as monogenean worms, rely on direct contact between hosts. Ectoparasitic arthropods may rely on host-host contact (e.g. many lice), shed eggs that survive off the host (e.g. fleas), or wait in the external environment for an encounter with a host (e.g. ticks). Some aquatic leeches locate hosts by sensing movement and only attach when certain temperature and chemical cues are present.

Some parasites modify host behavior in order to increase the transmission between hosts, often in relation to predator and prey (parasite increased trophic transmission). For example, in California salt marshes, the fluke *Euhaplorchis californiensis* reduces the ability of its killifish host to avoid predators.[38] This parasite matures in egrets, which are more likely to feed on infected killifish than on uninfected fish. Another example is the protozoan *Toxoplasma gondii*, a parasite that matures in cats but can be carried by many other mammals. Uninfected rats avoid cat odors, but rats infected with *T. gondii* are drawn to this scent, which may increase transmission to feline hosts.[39]

Roles in ecosystems

Modifying the behavior of infected hosts, to make transmission to other hosts more likely to occur, is one way parasites can affect the structure of ecosystems. For example, in the case of *Euhaplorchis californiensis* (discussed above) it is plausible that the local predator and prey species might be different if this parasite were absent from the system.

Although parasites are often omitted in depictions of food webs, they usually occupy the top position. Parasites can function like keystone species, reducing the dominance of superior competitors and allowing competing species to co-exist.

Many parasites require multiple hosts of the different species to complete their life cycles and rely on predator-prey or other stable ecological interactions to get from one host to another. In this sense, the parasites in an ecosystem reflect the health of that system.

Value

Although parasites are generally considered to be harmful, the eradication of all parasites would not necessarily be beneficial. Parasites account for as much as or more than half of life's diversity; they perform an important ecological role (by weakening prey) that ecosystems would take some time to adapt to; and without parasites organisms may eventually tend to asexual reproduction, diminishing the diversity of sexually dimorphic traits.[40] Parasites provide an opportunity for the transfer of genetic material between species. On rare, but significant, occasions this may facilitate evolutionary changes that would not otherwise occur, or that would otherwise take even longer.[3]

See also

- Coinfection
- Consumer-resource systems
- Endosymbiotic theory
- Fish diseases and parasites
- Human parasites
- Hyperparasite
- Infection
- Intestinal parasite
- List of parasites of humans
- List of parasitic organisms
- Macroparasite
- Microparasite
- Monoxenous development
- Myco-heterotrophy
- Parasitic plant
- Parasitoid wasp
- Pathogen
- Superparasitism
- Symbiosis
- Teratology
- The Extended Phenotype
- Toxoplasmosis

References

1. Leong, K. L. H.; M. A. Yoshimura; H. K. Kaya; H. Williams (1997). "Instar Susceptibility of the Monarch Butterfly (*Danaus plexippus*) to the Neogregarine Parasite, *Ophryocystis elektroscirrha*". *Journal of Invertebrate Pathology*. **69** (1): 79–83. doi:10.1006/jipa.1996.4634. PMID 9028932. Lay summary.
2. Bartel, Rebecca; Oberhauser, Karen; De Roode, Jacob; Atizer, Sonya (February 2011). "Monarch butterfly migration and parasite transmission in eastern North America". *Ecology*. **92** (2): 342–351. doi:10.1890/10-0489.1. PMID 21618914.
3. Claude Combes, *The Art of being a Parasite*, U. of Chicago Press, 2005
4. Getz WM (2011). "Biomass transformation webs provide a unified approach to consumer-resource modelling". *Ecol. Lett*. **14** (2): 113–24. doi:10.1111/j.1461-0248.2010.01566.x. PMC 3032891. PMID 21199247.
5. "The Differences Between Parasites and Parasitoids". BugLife. Retrieved 2013-07-19.
6. Godfray HC (2004). "Parasitoids". *Current Biology Magazine*. **14** (12): R456. doi:10.1016/j.cub.2004.06.004. PMID 15203011.
7. H.Charles J Godfray (22 June 2004). "Parasitoids". *Current Biology*. Vol. 14 no. 2. p. R456. doi:10.1016/j.cub.2004.06.004. Archived (https://web.archive.org/web/20081224082002/http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VRT-4CNT0D6-4&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_version=1&_urlVersion=0&_userid=10&md5=3c7a3e2fbf44ccce8f7e74d13c1a72a9) 24 December 2008 at the Wayback Machine.
8. παράσιτος (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dpara%2Fsitos), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus Digital Library
9. παρά (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dpara%2F), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus Digital Library
10. σῖτος (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dsi%3Dtos), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus Digital Library
11. σιτισμός (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.04.0057%3Aentry%3Dsitismo%2Fs), Henry George Liddell, Robert Scott, *A Greek-English Lexicon*, on Perseus Digital Library
12. Toussaint-Samat, M. (2009) A History of Food. Wiley-Blackwell Publishers.
13. Donahue, J.F. (2014) Food and Drink in Antiquity: A Sourcebook: Readings from the Graeco-Roman World. Bloomsbury Publishers.
14. "A CLASSIFICATION OF ANIMAL-PARASITIC NEMATODES". *plpnemweb.ucdavis.edu*.
15. Garcia LS (1999). "Classification of Human Parasites, Vectors, and Similar Organisms" (PDF). *Clin Infect Dis*. **29** (4): 734–6. doi:10.1086/520425. PMID 10589879.
16. C.E. Hopla; L.A. Durden; J.E. Keirans. "Ectoparasites and classification" (PDF). *Rev. sci. tech. Off. int. Epiz*. **13** (4): 985–1017.
17. "Pathogenic Parasitic Infections". PEOI. Retrieved 2013-07-18.
18. Thomas JA, Schönrogge K, Bonelli S, Barbero F, Balletto E (2010). "Corruption of ant acoustical signals by mimetic social parasites: Maculinea butterflies achieve elevated status in host societies by mimicking the acoustics of queen ants". *Commun Integr Biol*. **3** (2): 169–71. doi:10.4161/cib.3.2.10603. PMC 2889977. PMID 20585513.
19. Van Oystaeyen, Annette; Araujo Alves, Denise; Caliari Oliveira, Ricardo; Lima do Nascimento, Daniela; Santos do Nascimento, Fábio; Billen, Johan; Wenseleers, Tom (2013-09-01). "Sneaky queens in Melipona bees selectively detect and infiltrate queenless colonies". *Animal Behaviour*. **86** (3): 603–609. doi:10.1016/j.anbehav.2013.07.001.
20. "Social Parasites in the Ant Colony". Antkeepers. Retrieved 4 April 2016.
21. "Bullies of the Bird World". *National Wildlife Magazine*. Aug/Sep 1997, Vol. 35 No. 5 [1] (http://www.nwf.org/nationalwildlife/article.cfm?issueID=13&articleID=662)
22. O'Brien, Timothy G. (1988). "Parasitic nursing behavior in the wedge-capped capuchin monkey (Cebus olivaceus)". *American Journal of Primatology*. **16** (4): 341–344. doi:10.1002/ajp.1350160406.
23. Featured Creatures (http://entnemdept.ufl.edu/creatures/beneficial/encarsia_perplexa.htm)
24. Larry Gonick and Mark Wheelis, *The Cartoon Guide to Genetics*. HarperCollins, 1991.
25. "Host-Parasite Interactions Innate Defenses of the Host" (PDF). University of Colorado website.
26. Maizels RM (2009). "Parasite immunomodulation and polymorphisms of the immune system". *J. Biol*. **8** (7): 62. doi:10.1186/jbiol166. PMC 2736671. PMID 19664200.

27. Jeanne Robert L (1979). "Construction and Utilization of Multiple Combs in Polistes canadensis in Relation to the Biology of a Predaceous Moth". *Behavioral Ecology and Sociobiology*. **4** (3): 293–310. doi:10.1007/bf00297649.
28. Runyon JB, Mescher MC, De Moraes CM (2010). "Plant defenses against parasitic plants show similarities to those induced by herbivores and pathogens". *Plant Signal Behav*. **5** (8): 929–31. doi:10.4161/psb.5.8.11772. PMC 3115164. PMID 20495380.
29. .Hatcher, J. M. & Dunn, M. A. (2011). *Parasites in Ecological Communities*. Cambridge, UK: Cambridge University Press.
30. Frank SA (2000). "Specific and non-specific defense against parasitic attack". *J. Theor. Biol*. **202** (4): 283–304. doi:10.1006/jtbi.1999.1054. PMID 10666361.
31. Price, P.W. 1980. Evolutionary Biology of Parasites. Princeton University Press, Princeton
32. Wolff, Ewan D. S.; Steven W. Salisbury; John R. Horner; David J. Varricchio (2009). Hansen, Dennis Marinus, ed. "Common Avian Infection Plagued the Tyrant Dinosaurs". *PLoS ONE*. **4** (9): e7288. doi:10.1371/journal.pone.0007288. PMC 2748709. PMID 19789646. Retrieved 2013-07-08.
33. Rook GA (2007). "The hygiene hypothesis and the increasing prevalence of chronic inflammatory disorders". *Transactions of the Royal Society of Tropical Medicine and Hygiene*. **101** (11): 1072–4. doi:10.1016/j.trstmh.2007.05.014. PMID 17619029.
34. Werren, John H. (February 2003). "Invasion of the Gender Benders: by manipulating sex and reproduction in their hosts, many parasites improve their own odds of survival and may shape the evolution of sex itself" (Reprint). *Natural History*. **112** (1): 58. ISSN 0028-0712. OCLC 1759475. Retrieved 15 November 2008.
35. Switzer WM, Salemi M, Shanmugam V, Gao F, Cong ME, Kuiken C, Bhullar V, Beer BE, Vallet D, Gautier-Hion A, Tooze Z, Villinger F, Holmes EC, Heneine W (2005). "Ancient co-speciation of simian foamy viruses and primates". *Nature*. **434** (7031): 376–80. doi:10.1038/nature03341. PMID 15772660.
36. Rózsa L, Reiczigel J, Majoros G (2000). "Quantifying parasites in samples of hosts". *J. Parasitol*. **86** (2): 228–32. doi:10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2. PMID 10780537.
37. Lively CM, Dybdahl MF (2000). "Parasite adaptation to locally common host genotypes". *Nature*. **405** (6787): 679–81. doi:10.1038/35015069. PMID 10864323.
38. Lafferty KD, Morris AK (1996). "Altered behavior of parasitized killifish increases susceptibility to predation by bird final hosts". *Ecology*. **77**: 1390. doi:10.2307/2265536.
39. Berdoy M, Webster JP, Macdonald DW (2000). "Fatal attraction in rats infected with *Toxoplasma gondii*". *Proc. Biol. Sci*. **267** (1452): 1591–4. doi:10.1098/rspb.2000.1182. PMC 1690701. PMID 11007336.
40. Holt RD (2010). "IJEE Soapbox". *Israel Journal of Ecology and Evolution*. **56** (3): 239–250. doi:10.1560/IJEE.56.3-4.239.

Further reading

- Zimmer, Carl (2001). *Parasite Rex*. Free Press. p. 320. ISBN 0-7432-0011-X.
- Combes, Claude (2005). *The Art of Being a Parasite*. The University of Chicago Press. p. 280. ISBN 0-226-11438-4.
- Desowitz, Robert (1998). *Who Gave Pinta to the Santa Maria?*. Harvest Books. p. 264. ISBN 0-15-600585-9.
- Vinn, O., Wilson, M.A., Mõtus, M.-A. and Toom, U. (2014). "The earliest bryozoan parasite: Middle Ordovician (Darriwilian) of Osmussaar Island, Estonia". *Palaeogeography Palaeoclimatology Palaeoecology*. **414**: 129–132. doi:10.1016/j.palaeo.2014.08.021. Retrieved 2014-01-09.
- Vinn, O., Wilson, M.A., and Toom, U. (2014). "Earliest rhynchonelliform brachiopod parasite from the Late Ordovician of northern Estonia (Baltica)". *Palaeogeography Palaeoclimatology Palaeoecology*. **411**: 42–45. doi:10.1016/j.palaeo.2014.06.028. Retrieved 2014-01-09.

External links

Wikimedia Commons has media related to ***Parasites***.

- Parasitism (http://knol.google.com/k/klaus-rohde/parasitism-an-introduction-to/xk923bc3gp4/51#)—Knol
- Toxoplasmosis (http://www.cdc.gov/toxoplasmosis/)
- Parasitology Parasites Zoonoses (http://www.parazytologia.pl)—(Polish/English) over 50 movies (Filmoteka) and over 250 photos (Fotogaleria/Photogallery) with human and animal parasites.

- Aberystwyth University: Parasitology (http://www.aber.ac.uk/~mpgwww/Edu/EduIndex.html)—class outline with links to full text articles on parasitism and parasitology.
- KSU: Parasitology Research (http://www.k-state.edu/parasitology)—parasitology articles and links.
- Medical Parasitology (http://pathmicro.med.sc.edu/book/parasit-sta.htm)—online textbook.
- Division of Parasitic Diseases (http://www.cdc.gov/ncidod/dpd/), Centers for Disease Control and Prevention
- VCU Virtual Parasite Project (http://www.vcu.edu/csbc/vpp/)—Virtual Parasite Project at Virginia Commonwealth University's Center for the Study of Biological Complexity
- Parasites World (http://www.parasites-world.com/)—Parasites articles and links.
- Parasitic and Parasitoid Alien Species in Science Fiction Movies (http://www.explore-science-fiction-movies.com/parasiticparasitoidalienswikipedia)
- Toxoplasma gondii in the Subarctic and Arctic (http://www.actavetscand.com/content/pdf/1751-0147-52-S1-S7.pdf)
- Parasitic Insects, Mites and Ticks: Genera of Medical and Veterinary Importance (https://en.wikibooks.org/wiki/Parasitic_Insects,_Mites_and_Ticks:_Genera_of_Medical_and_Veterinary_Importance/Introduction) Wikibooks

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